Low Gallonage Spraying of Vegetable Crops

By G. E. R. Hervey and W. W. Gunkel

New York State Agricultural Experiment Station,
Cornell University, Geneva, N. Y.

BULLETIN NO. 753 • MAY 1952

Table of Contents

A publication of the
New York State Agricultural Experiment Station,
Geneva, N. Y.,
New York State College of Agriculture,
A unit of the State University of New York
At Cornell University

BULLETIN No. 753

Low Gallonage Spraying of Vegetable Crops

G. E. R. HERVEY AND W. W. GUNKEL[1]

Abstract

EXPERIMENTS are reported which deal with the application of insecticides with a low volume weed control type sprayer for the control of insect pests of cabbage and peas, the Mexican bean beetle, and the six-spotted leafhopper.

Satisfactory control of these insect pests was obtained.

The prinicipal advantage of the low volume method of insecticide application is that it reduces the cost of insect control. The sprayer is tractor-mounted and is adapted for applying insecticides by using drop pipe and nozzle arrangements which are varied according to the type of growth of the crop to be sprayed.

There are several different kinds of pumps available for a sprayer of this type. A rotary gear pump with a capacity of 8 to 10 gallons per minute is satisfactory. It may be operated from the tractor power take-off. The boom is 12 feet long, a length sufficient to cover four rows of most crops. It is mounted on the front of the tractor.

Nozzles which give a flat, fan-type spray pattern have been found to be the most satisfactory. The sprayer is operated at a pressure of 80 pounds per square inch and should be equipped with nozzles which apply about 20 gallons per acre.

Introduction

AN inexpensive tractor-mounted sprayer was tested extensively for the control of insect pests of beans, cabbage, broccoli, carrots, and peas in western New York from 1949 through 1951. The results obtained experimentally have been encouraging and growers who first used the sprayer extensively in 1951 report equally good results.

The machine is of the same design as the equipment used for chemical weed control. It was adapted for applying insecticides to row crops by using nozzle arrangements designed to give maximum coverage of the insecticide to the crops treated and by using a somewhat higher pressure than ordinarily used for applying herbicides. The designation low

[1]Professor of Entomology, New York State Agricultural Experiment Station, and Assistant Professor, Agricultural Engineering Department, New York State College of Agriculture, respectively. The writers wish to express their appreciation to Orion Clark for valuable assistance in carrying out the experimental work, and to W. H. Ashton of the Department of Agricultural Engineering who prepared the drawings used in this bulletin.

volume or low gallonage spraying as used in this bulletin refers to the application of the insecticide in about 20 gallons of water per acre.

The weed control type sprayer has been used rather extensively for applying insecticides for the control of forage crop insects, but it has had only a limited use on vegetables heretofore. Medler and Chamberlin[2] report satisfactory control of various forage crop pests using a low volume weed control sprayer. The insecticides were used in the form of wettable powders and emulsions. Weaver,[3] Chamberlin and Medler,[4] and Marshall and Gyrisco[5] obtained good control of the meadow spittlebug on legume crops using low volume equipment of the weed control type. Dahms[6] showed that a low volume sprayer gave unsatisfactory control when a parathion wettable powder suspension was used without agitation against the greenbug on grains. Parathion and Metacide emulsions, however, gave good results when applied with the same equipment. Davich and Apple,[7] using a low pressure weed control type sprayer, obtained excellent control of the pea aphid with parathion and other phosphate insecticides when the treatments were applied in 5 to 15 gallons of water per acre.

The first part of this bulletin includes a brief discussion of the sprayer used and the results obtained in experiments against the insect pests of various vegetable crops. The second section is concerned with the details of the construction of sprayers suitable for low volume insecticide application.

Experimental Sprayer

The sprayer used in the experiments will be discussed in greater detail in a later section of this bulletin, but for the convenience of the reader a brief description follows. It is mounted on a tractor (Figs. 1 and 2) and consists of the pump, connecting hose, spray tank, boom, boom-mounting bracket, drop pipes, and nozzles. The pump is the rotary external gear type and is operated by the tractor's power take-off. It has a capacity of 8 gallons per minute at 500 R.P.M. at a pressure of

---

[2]Medler, J. T., and Chamberlin, T. R. Low pressure spraying equipment for control of some forage insects. *Jour. Econ. Ent., 42: 239–243. 1949.*

[3]Weaver, C. R. Meadow spittlebug control with low and high volume insecticide applications. *Jour. Econ. Ent., 44: 163–166. 1951.*

[4]Chamberlin, T. R., and Medler, J. T. Further tests of insecticides to control meadow spittlebugs on alfalfa. *Jour. Econ. Ent., 43: 888–891. 1950.*

[5]Marshall, D. S., and Gyrisco, G. G. Control of the meadow spittlebug on forage crops. *Jour. Econ. Ent., 44: 289–293. 1951.*

[6]Dahms, R. G. Insecticide formulations and equipment used for greenbug control. *Jour. Econ. Ent., 44: 954–957. 1951.*

[7]Davich, T. B., and Apple, J. W. Pea aphid control with contact and systemic insecticidal sprays. *Jour. Econ. Ent., 44: 528-533. 1951.*

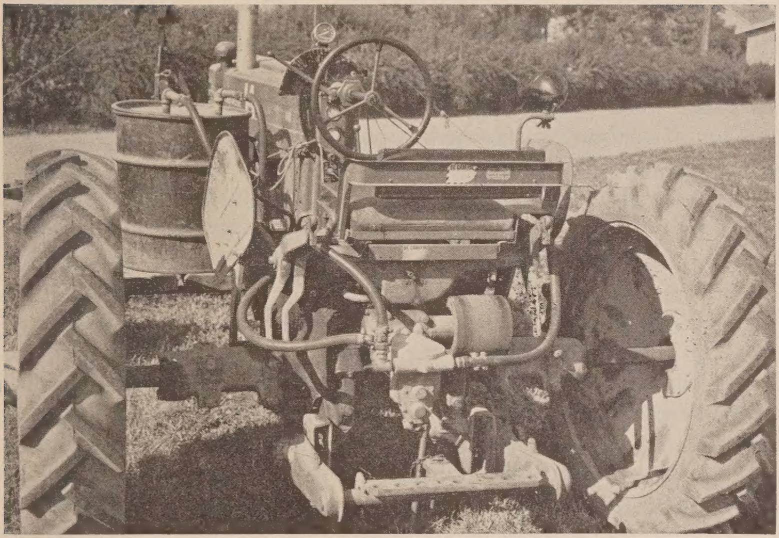

FIG. 1.—Rear view of sprayer, showing pump mounted on the power take-off, connecting hose, and spray tank.

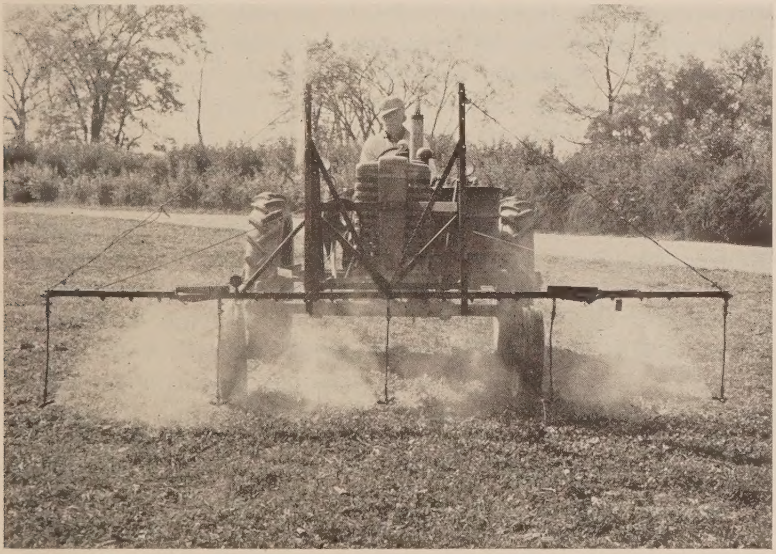

FIG. 2.—Front view of sprayer, showing boom and drop pipe arrangement used for spraying beans.

zero P.S.I.[8] It has a pressure relief valve. This pump has been used extensively for two years and has given satisfactory service.

The tank consists of a 20-gallon steel barrel fitted with a splash-proof cover and mounted on a small platform on the side of the tractor. The pump suction-line and the by-pass line enter the tank through two pieces of $\frac{3}{4}$-inch galvanized iron pipe which are welded to the cover of the tank. The suction line which opens near the bottom of the tank is fitted with a 100-mesh wire screen strainer. The hose used in the suction line, by-pass line, and the discharge line from the pump to the boom is $\frac{3}{4}$-inch size and high pressure type.

The boom is supported on the front of the tractor by means of two pieces of angle iron bolted to the tractor in a vertical position. This arrangement permits the boom to be raised and lowered depending on the height of the crop to be treated. The boom is 12 feet long and is reinforced by a piece of angle iron. It is made of $\frac{1}{2}$-inch hard copper tubing and is put together with tee fittings, $\frac{1}{2}$ x $\frac{1}{2}$ x $\frac{1}{4}$ inch, spaced so that drop pipes can be used on crops of different row widths. Mounted on the boom is the pressure gauge which is in view of the operator. The drop pipes are copper, $\frac{1}{4}$ inch in diameter, and approximately 20 inches long. The drop pipe is fitted with a short piece of rubber hose which makes it flexible and prevents breakage. A double swivel connector is fitted on the bottom of each drop pipe and the nozzles are mounted in the opening in each side of this attachment. The number of nozzles used and the arrangement depend on the crops being treated. The arrangements used for spraying cabbage, broccoli, beans, peas, and carrots are shown in detail later.

The Teejet nozzle[9] was used in the experiments discussed in this bulletin. Nozzle tips which produce a flat, fan-shaped spray pattern were used almost exclusively. Three nozzle tips with different orifice size openings have been used for the most part in this sprayer. These are designated by the manufacturer as 8001, 80015, and 8002. These orifice tips have an 80° fan angle and a rated discharge capacity at a pressure of 80 P.S.I. of 0.14, 0.21, and 0.28 G.P.M., respectively.

The sprayer has been operated at speeds of 3 to 5 M.P.H. and at a pressure of 80 P.S.I. The amount of solution applied per acre has ranged from 10 to 25 gallons. Using a four-row boom and operating

[8]Abbreviations used in this bulletin:

R.P.M. = Revolutions per minute.	G.P.A. = Gallons per acre.
P.S.I. = Pounds per square inch.	M.P.H. = Miles per hour.
G.P.M. = Gallons per minute.	H.P. = Horse power.

[9]Manufactured by the Spraying Systems Co., 3201 Randolph Street, Bellwood, Ill.

the tractor at about 4 M.P.H., it is possible to treat 3½ to 4 acres of crop per hour.

Experimental Procedure

The experimental plots were four rows wide in most cases and varied in size from $^{1}/_{7}$ to ¼ acre. The plan of the experiments consisted of a randomized block design in which the number of replicates varied from two to four. The insect records were taken in most cases from the two center rows of each plot.

The results given for cabbage caterpillar control are based on an estimate made at the end of the season on the total injury sustained by the plant from both the imported cabbage worm and the cabbage looper. This estimate was obtained by assigning each plant to one of four arbitrarily selected injury categories. An injury index was calculated from these data for each plot and treatment. The index is calculated as follows: number of plants in each category multiplied by the category number. The sum of the product is divided by the number of plants observed. This value represents the average injury per plant based on the arbitrary scale selected. In order better to visualize the difference between treatments, the index is then transposed to "per cent control efficiency". In the 1949 cabbage insect experiment the control of the cabbage aphid is based on the number of plants showing severe aphid injury. These plants included those which were covered with honeydew and blackened and those on which the leaves were encrusted with aphids. The leaves of the more severely injured plants had dropped and the only part remaining was a small blackened head.

Dusts were purposely omitted from the cabbage insect experiments, although they would have been desirable for comparative purposes. This was done to avoid insecticide drift to adjacent plots. DDT dusts are particularly toxic to cabbage caterpillars and any appreciable drift of the material would have interfered with the experimental plan.

The Mexican bean beetle records in the 1949 and 1950 experiments were obtained by counting the number of surviving larvae and pupae on four groups of 25 plants selected at random in each plot. These counts were made about one week after the second application. It was observed during 1950 that the larval counts did not always accurately reflect the total damage caused by the larvae. It was noted that in some plots where only small differences were shown in efficiency, based on larval counts, striking differences developed later in visible plant injury. This situation may be accounted for on the basis of differences in residual action of the several insecticides tested. Plant injury

was taken into consideration in the 1951 experiment in addition to insect counts in determining efficiency ratings of the insecticides. The foliage of each plot was graded on the basis of the amount of insect feeding present on the beans near maturity. For the arbitrary scale used to classify the different degrees of injury, 0 denotes no injury while 6 indicates severe injury or almost complete defoliation.

The broccoli insect data were obtained by removing and counting the number of insects in 25 broccoli spears selected at random from each plot. The insects were removed from the samples for counting by means of a Berlese funnel.

Materials Used

DDT emulsion. — This product contains 25 per cent actual DDT. It was obtained from the Rohm and Haas Company, Philadelphia, Pa., and from the G.L.F. Soil Building Service, Ithaca, N. Y.

Dilan emulsion. — The active ingredients of this product consist of two parts by weight of 2–nitro–1, 1–bis (p-chlorophenyl) butane and one part of 2–nitro–1, 1–bis (p-chlorophenyl) propane. The emulsion contained 25 per cent of the toxicants. Supplier: The Commercial Solvents Corporation, Terre Haute, Ind.

Parathion. — In 1949 a wettable powder containing 25 per cent actual parathion was used. In 1950 and 1951 this material was used as a 25 per cent emulsion. This is now a standard material. Supplier: American Cyanamid Corporation, New York, N. Y.

Metacide emulsion. — An experimental phosphate insecticide containing 6.2 per cent parathion (O, O-diethyl O-p-nitrophenyl thiophosphate), 24.5 per cent O, O-dimethyl O-p-nitrophenyl thiophosphate, 2.7 per cent related organic phosphates, and 66.6 per cent inert ingredients. Supplier: Chemagro Corporation, New York, N. Y.

Potasan emulsion. — An experimental phosphate insecticide containing 32 per cent of diethoxy thiophosphoric ester of 4-methyl 7-hydroxy coumarin. Supplier: Chemagro Corporation, New York, N. Y.

Systox emulsion. — A systemic insecticide containing 50 per cent trialkyl thiophosphate. Supplier: Chemagro Corporation, New York, N. Y.

Malathon emulsion. — A product containing 50 per cent of S-(1,2-dicarbethoxyethyl)-O,O-dimethyl dithiophosphate. Supplier: American Cyanamid Corporation, New York, N. Y.

TEPP. — A standard liquid insecticide containing 20 per cent tetraethyl pyrophosphate. Supplier: California Spray Chemical Company, Richmond, Calif.

Lindane. — A wettable powder containing 25 per cent lindane. Supplier: California Spray Chemical Company, Richmond, Calif.

Methoxychlor emulsion. — A product containing 25 per cent actual methoxychlor. Supplier: E. I. duPont de Nemours and Company, Inc. (Grasselli Chemicals), Wilmington, Del.

Rotenone. — A rotenone resin emulsion containing 1.5 per cent

rotenone was used in 1949. Supplier: Niagara Chemical Division, Food Machinery and Chemical Corporation, Middleport, N. Y. An emulsion containing 2 per cent rotenone, 0.2 per cent pyrethrum, and 2 per cent piperonyl cyclonene was used in 1950. Supplier: U. S. Industrial Chemicals, Inc., New York, N. Y.

Experiments in 1949

Cabbage Insects

The principal insects involved in the cabbage experiments were the imported cabbage worm, *Pieris rapae* (L.), the cabbage looper, *Trichoplusia ni* (Hbn.), and the cabbage aphid, *Brevicoryne brassicae* (L.). The standard recommendation for the commercial control of these insects on the late or main crop of cabbage in western New York consists of using DDT for cabbage caterpillars and parathion, TEPP, or nicotine for the cabbage aphid. A common practice, followed for the control of all three species, is to use a combination dust containing 3 per cent DDT and 1 per cent parathion. These materials and others were tested in low volume sprays for cabbage insect control.

The 1949 experiment (Table 1) was located in a commercial planting of cabbage which was very heavily infested with cabbage worms and cabbage aphid. These pests were active from about the middle of July until the middle of September and caused heavy losses in both the yield and quality of the crop.

It will be noted that DDT, either alone or in any of the combination treatments in which it was used, gave excellent control of cabbage worms. TEPP, as well as the DDT-TEPP and DDT-lindane combinations, gave good control of cabbage aphid. A good appraisal of the total damage caused by the insects in this field may be seen from the relatively small percentage of plants which formed marketable heads on the untreated plot. The amount of this type of damage is also a good criterion for evaluating the treatments for the combined control of all insects. It will be noted that the DDT-TEPP and DDT-lindane combinations were outstanding in this respect.

Mexican Bean Beetle

One low gallonage spraying experiment was conducted against the Mexican bean beetle, *Epilachna varivestis* Muls., in 1949 (Table 2). The treatments were applied July 14 and 21 and the infestation record was taken July 29. The sprays were used at the rate of 25 gallons per acre and the rotenone dust at 45 pounds per acre. All of the materials tested as sprays in this experiment gave satisfactory control of the bean

TABLE 1.—*Control of cabbage caterpillars and cabbage aphid with low volume sprays, Geneva, N. Y., 1949.*

MATERIALS*	AMOUNT USED IN 20 GALLONS OF WATER PER ACRE	AVERAGE INDEX CABBAGE WORM INJURY	PER CENT CABBAGE WORM CONTROL	PER CENT PLANTS SEVERELY INJURED BY CABBAGE APHID	PER CENT PLANTS WITH MARKETABLE HEADS
DDT emulsion, 25%	1 qt.	0.067	87.4	23.5	68.1
DDT emulsion, 25%	2 qts.	0.039	98.5	36.2	69.1
TEPP, 20%	1 qt.	1.990	22.5	7.5	64.7
DDT emulsion, 25% Parathion, 25% w.p.	1 qt. 1 lb.	0.089	96.5	25.1	74.9
DDT emulsion, 25% TEPP, 20%	1 qt. 1 qt.	0.078	96.9	9.9	88.9
DDT emulsion, 25% Lindane, 25% w.p	1 qt. 1 lb.	0.111	95.7	13.0	84.0
Check		2.567	—	45.5	30.8
L.S.D. 5% level		0.669		2.5	15.8
1% level		0.990		5.4	32.3

*Treated July 28 and Aug. 9 and 25.

TABLE 2.—*Mexican bean beetle control with low gallonage sprays and dust, Geneva, N. Y., 1949.*

MATERIALS*	AMOUNTS USED IN 25 GALLONS WATER FOR SPRAYS	AVERAGE NUMBER LARVAE ON 100 PLANTS	PER CENT CONTROL
Rotenone resin conc., 1.5%	1 qt.	57	95.0
Methoxychlor emulsion, 25%	1 qt.	100	91.3
Parathion, 25% w.p.	1 lb.	10	99.1
Rotenone dust, 1%	——	8	99.3
Check	——	1,155	——

*Treated July 14 and 21. Larval counts made July 29.

beetle and compared favorably with rotenone dust. Parathion seemed to be especially promising.

The 1949 low gallonage spraying experiments, while being of a preliminary nature, showed that this method of insecticide application held considerable promise for Mexican bean beetle and cabbage insect control. It was found that wettable powders were unsuitable for use in this type of equipment. This was because of the lack of agitation in the spray tank and the tendency of suspensions to settle to the bottom. Trouble was also encountered with nozzle clogging when wettable powders were used. The 1949 experiences showed that more information was needed on optimum pressure, concentration of the solution, formulations, and nozzle type and arrangement.

Experiments in 1950

Mexican Bean Beetle

The 1950 Mexican bean beetle experiment was conducted in an 8-acre field of red kidney beans (Table 3). The materials were applied twice, on July 13 and 20, and the larval survival counts were made on July 31. At the time of the first application the bean beetle eggs were hatching and practically all the larvae present were in the first and second instar. There were still many overwintering adults present at this time, but their numbers were greatly reduced by the first application and there was little additional egg laying. The dusts were applied with a row crop power duster at the rate of 35 to 40 pounds per acre. These dusts were the formulations currently being recommended for Mexican bean beetle control and were included in this experiment for comparison with the sprays.

The results show that parathion emulsion was the most effective spray treatment tested. At the time the counts were made no difference in control was shown between 1 pint of parathion and ½ pint when used in 20 gallons of water per acre at 80 pounds pressure. Observations

TABLE 3.—*Low gallonage spraying experiment for Mexican bean beetle control, Geneva, N. Y., 1950.*

Materials*	Amount used per acre: Insecticide formulation	Amount used per acre: Water, gallons	Pressure, lbs. per sq. in.	Nozzle type	Average number larvae per 100 plants†	Per cent control
Parathion, 25% emulsion	1 pt.	20	80	Fan	0.6	99.9
Parathion, 25% emulsion	½ pt.	20	80	Fan	10.3	98.9
Parathion, 25% emulsion	½ pt.	10	80	Fan	4.3	99.5
Parathion, 25% emulsion	½ pt.	10	40	Fan	48.0	94.7
Parathion, 25% emulsion	½ pt.	20	40	Fan	105.0	88.5
Parathion, 25% emulsion	½ pt.	20	80	Cone	115.6	87.3
Parathion, 25% emulsion	½ pt.	10	80	Cone	134.6	85.2
Parathion, 25% emulsion	½ pt.	10	40	Cone	114.6	87.4
TEPP, 20%	1 pt.	20	80	Fan	190.6	79.1
TEPP, 20%	½ pt.	20	80	Fan	240.3	73.6
Rotenone-pyrethrum liquid conc.‡	2 qts.	20	80	Fan	166.3	81.7
Rotenone, 1% dust	—	—	—	—	4.6	99.5
Rotenone ¾% and DDT 2% dust	—	—	—	—	0.3	99.9
Parathion, 1% dust	—	—	—	—	10.0	98.9
Check	—	—	—	—	911.0	—
L.S.D. 5% level					106	
1% level					144	

*Materials applied July 13 and 20.
†Larval counts made July 31.
‡Rotenone 2%, pyrethrins 0.2%, piperonyl cyclonene 2%.

made later in the season, however, showed that there was more bean beetle feeding on the plots treated with ½ pint than on those treated with 1 pint. This difference probably was due to the greater residual effect of the 1 pint concentration. There was no difference in control between plots treated with ½ pint of parathion in 10 gallons of water per acre and those treated with the same amount in 20 gallons. Reducing the pressure from 80 P.S.I. to 40 P.S.I., however, did tend to reduce the insect control. Here again, the larval count does not show this clearly. It was much more noticeable in observation on larval feeding made later in the season as the beans were approaching maturity. This difference in control observed between 80 pounds and 40 pounds can be accounted for by better spray penetration at the higher pressure. The treatments applied with the cone-type nozzles were not as effective in killing the insect as comparable treatments applied with fan-type nozzles.

Cabbage Insects

The cabbage insect experiment was conducted in a commercial planting of cabbage (Table 4). The insect populations were low as compared with those reported in the 1949 experiment. The treatments were applied on July 26 and August 9 and 22. It was during this period that the principal activity of the insects occurred. DDT emulsion again gave excellent control of cabbage worms and there appeared to be little difference between concentrations of 1 and 2 pints. However, it should be noted that these results were obtained with a light infestation. It is again indicated that the treatments applied with fan-type nozzles were more effective than comparable treatments applied with the cone type. Attention is directed to the fact that the aphid infestation

TABLE 4.—*Control of cabbage caterpillars and cabbage aphid with low volume sprays, Geneva, N. Y., 1950.*

MATERIALS*	AMOUNT OF INSECTICIDE USED IN 20 GALS. OF WATER PER ACRE AT 80 LB. PRESSURE	NOZZLE TYPE	PER CENT CONTROL CABBAGE WORMS	PER CENT PLANTS INFESTED WITH APHIDS
DDT emulsion, 25%	2 pts.	Fan	98.7	58.1
DDT emulsion, 25%	1 pt.	Fan	94.0	50.1
DDT emulsion, 25%	1 pt.	Cone	83.7	58.1
{DDT emulsion, 25%	1 pt.	Fan	94.8	12.3
{Parathion emulsion, 25%	1 pt.			
{DDT emulsion, 25%	1 pt.	Fan	91.8	16.2
{TEPP, 20%	1 pt.			
Check	——	——	——	22.1

*Treated July 26 and Aug. 9 and 22.

was lower on the check plot than on the DDT-treated plots. This is a condition frequently observed when DDT is used, and it is probably due to the destruction of the parasites and predators of the aphid. The DDT-TEPP and DDT-parathion combination sprays reduced the number of aphid-infested plants below that of the other treatments.

Carrot Yellows

Experiments were carried out in 1949 and 1950 using low gallonage spraying for the control of the six-spotted leafhopper, *Macrosteles divisus* (Uhl.), the vector of carrot yellows. The leafhopper population and the incidence of yellows were very low in both years that the tests were run. The results obtained in the 1950 experiment are shown in Table 5. The experimental design consisted of four treatments randomized in a latin square, the plots being about ¼ acre in size. The standard spray treatment was applied with an orchard sprayer and a portable six-row boom. The sprayer was operated at 400 pounds pressure. The low gallonage sprays were applied at the rate of 20 G.P.A., using a pressure of 80 P.S.I. A six-row boom with two nozzles per row was used. The results are not conclusive because of the low incidence of yellows. The insect sweeping record indicates, however, that the low volume sprays were as effective in killing the leafhopper as the high volume spray treatment.

The 1950 experiments showed that in the case of the Mexican bean beetle, 1 pint of parathion emulsion applied in 10 to 20 gallons of water per acre at 80 P.S.I. would give adequate control of this insect. The cabbage insect experimental results confirm those of the previous

TABLE 5.—*A comparison between standard spraying and low volume spraying for the control of the six-spotted leafhopper and carrot yellows, Geneva, N. Y., 1950.*

MATERIAL AND RATE OF APPLICATION*	LEAFHOPPERS COLLECTED IN 10 SWEEPS OF NET						PER CENT YELLOWS	
	Aug. 15	Aug. 22	Aug. 25	Aug. 30	Sept. 6	Oct. 2	Aug. 15	Nov. 1
DDT (50% w.p.), 4 pounds+Orthol K, 2 qts. per 100 gallons water	1.7	0.6	2.0	0.0	0.3	5.0	0.56	0.82
DDT, 25% emulsion, 4 qts. per 20 gallons water	0.0	0.2	4.0	0.1	0.4	3.9	0.56	1.38
DDT, 25% emulsion, 2 qts. per 20 gallons water	0.5	0.8	4.5	0.1	0.4	4.4	0.32	0.75
Check	24.1	14.4	12.4	9.7	12.3	7.3	0.38	4.88
L.S.D. 5% level							0.028	0.12
1% level							0.042	0.19

*Treated Aug. 14 and 28.

year, showing that DDT emulsion is an effective control measure for cabbage worms.

Experiments in 1951

Mexican Bean Beetle

The 1951 bean beetle experiment was carried out in a 7-acre planting of red kidney beans. They were planted on May 30. The field became heavily infested with overwintering adults as the bean seedlings were emerging. The appearance of the adults was followed by a period of heavy egg laying and subsequently by a high larval population. The materials tested and the results obtained are shown in Table 6. The first treatment was applied July 11 as the eggs were beginning to hatch. A second application was made July 18 and the larval counts were taken July 26. As a further check on the efficiency of the materials tested, the foliage of each plot was graded on the basis of the amount of bean beetle feeding on August 13. The larval counts made in this experiment show that there was no significant difference between treatments, all formulations showing a high degree of toxicity to the insect. The foliage injury record made three weeks after the larval counts, however, showed some marked differences between treatments. It will be noted that in the case of the parathion spray and the rotenone dust, two applications were much more effective than one application. One pint of parathion is superior to ½ pint. Malathon was definitely less effective than the other materials tested and Dilan at the rates tested was outstanding.

Broccoli Insects

Broccoli was included as a test crop in 1951. While the insect pests of broccoli are the same as those which attack cabbage, the problem is quite different. To maintain the standards of quality required for broccoli grown for processing, it is necessary to keep the crop practically free from insects. This requires a very effective control program. Furthermore, the broccoli plant is comparatively large and presents a large leaf area which is difficult to cover uniformly with insecticides. The number of insecticides that can be safely used on broccoli during the harvesting period is very limited because of the danger of toxic residues either in or on the processed product.

The materials tested in this experiment were applied during the period when the broccoli was being harvested. Another series of treatments was tested in the same field during the period extending from the time the plants were set out until the first broccoli heads began to

TABLE 6.—*Mexican bean beetle low gallonage spraying experiment, Geneva, N. Y., 1951.*

MATERIALS*	AMOUNT USED PER ACRE		NUMBER APPLICATIONS	AVERAGE NUMBER LARVAE ON 100 PLANTS†	PER CENT CONTROL	AVERAGE INDEX OF FOLIAGE INJURY‡
	Gals. water	Insecticide				
Parathion emulsion, 25%	20	1 pt.	2	0.0	100.0	0.5
Parathion emulsion, 25%	20	½ pt.	2	9.3	99.5	1.3
Parathion emulsion, 25%	15	½ pt.	2	18.5	98.9	1.3
Parathion emulsion, 25%	20	1 pt.	1	32.8	98.1	2.3
Malathon emulsion, 50%	20	1 pt.	2	44.8	97.4	2.0
Malathon emulsion, 50%	20	½ pt.	2	127.8	92.7	2.8
Dilan emulsion, 25%	20	2 pts.	2	0.5	99.9	0.0
Dilan emulsion, 25%	20	1 pt.	2	12.3	99.3	0.2
Metacide emulsion, 33%	20	¾ pt.	2	31.0	98.2	1.3
Potasan emulsion, 32%	20	½ pt.	2	20.8	98.8	0.2
Rotenone dust, 1%	—	—	2	3.0	99.8	0.0
Rotenone dust, 1%	—	—	1	59.8	96.6	1.3
Parathion dust, 1%	—	—	2	25.8	98.5	1.5
Check	—	—	-	1,752.5	—	6.0
L.S.D. 5% level				249.3		1.27
1% level				334.5		1.70

*Treated July 11 and 18.
†Counts made July 26.
‡Foliage graded for bean beetle injury Aug. 13.

form. The infestation, however, during the time this schedule was being applied was too low to give conclusive results.

The cabbage aphid was the most important insect involved in the experiment. It became prevalent about the middle of August at the time the broccoli was beginning to form heads. Aphids were present in large numbers on the untreated plots from that time until early November when the plants were destroyed by freezing temperatures. The cabbage worm population was highest in late August. It dropped rapidly from that point and remained at a low level until the end of the season. Results of the test are shown in Table 7.

The regular treatments (plots 1, 2, and 3) were applied five times beginning on August 20. It will be noted that two changes were made in the experiment while it was in progress. The first involved the concentration of the materials being tested. In the first four applications the insecticides were used at the rate of 1 pint per acre. The insect record taken on September 25 showed clearly that 1 pint, even of the more effective materials, was not giving satisfactory control of the cabbage aphid. Accordingly, in the last application (October 4) the concentration of all the insecticides was doubled. The other change involved the two Systox treatments. These two treatments (plots 4 and 5) applied early in July showed some reduction in the aphid population in the record taken September 5, but the number of aphids on these plots in the September 12 samples was only slightly less than the check. The Systox plots as such were abandoned at this point. These two plots were then treated with TEPP (plot 4) and Metacide (plot 5) twice, namely, September 18 and October 4.

The cabbage aphid was maintained at a comparatively low level through the season by the TEPP and parathion treatments (plots 1 and 2). With the exception of the sample taken September 25, the aphid control secured with these two insecticides was above 90 per cent throughout the season. There is still a question, however, whether this degree of control would meet the standards required for processing broccoli. Malathon was definitely inferior to TEPP and parathion.

The cabbage worm infestation was too low to warrant any definite conclusions. It is interesting to note, however, that no worms were found in any of the samples taken from the parathion plots at any time during the season. A few worms were collected on all of the other treated plots.

It should be pointed out that this experiment was conducted under conditions which made the control of the cabbage aphid exceedingly difficult. The untreated checks and border rows were very heavily

TABLE 7. *Low gallonage spraying for the control of cabbage aphids and cabbage caterpillars on broccoli, Geneva, N. Y., 1951.*

PLOT No.	MATERIALS*	AMOUNT USED IN 20 GALLONS WATER PER ACRE	INSECTS PER 100 SPEARS OF BROCCOLI													
			Sept. 5		Sept. 12		Sept. 25		Oct. 7		Oct. 16		Oct. 23		Nov. 1	
			Aphids	Worms	Aphids	Worms	Aphids	Worms	Aphids	Worms	Aphids	Worms	Aphids	Worms	Aphids	Worms
1	TEPP, 20%	1 pt.	786	5	706	6	3,961	3								
	TEPP, 20%	2 pts.	—	—	—	—	—	—	533	2	939	1	1,278	1	1,460	2
2	Parathion, 25%	1 pt.	806	0	1,402	0	4,159	0								
	Parathion, 25%	2 pts.	—	—	—	—	—	—	542	0	1,085	0	1,299	0	1,756	0
3	Malathon, 50%	1 pt.	3,002	4	3,347	7	12,612	1								
	Malathon, 50%	2 pts.	—	—	—	—	—	—	4,960	0	4,273	0	4,463	0	6,743	0
4	Systox, 50%†	—	4,752	18	10,264	34										
	TEPP, 20%‡	1 pt.	—	—	—	—	10,864	9								
	TEPP, 20%	2 pts.	—	—	—	—	—	—	624	4	897	1	1,692	0	3,079	0
5	Systox, 50%§	¾ pt.	2,078	26	9,345	28										
	Metacide, 33%‡	¾ pt.	—	—	—	—	18,851	8								
	Metacide, 33%	1½ pts.	—	—	—	—	—	—	5,805	0	5,390	0	3,902	0	5,007	1
6	Check		12,040	104	15,345	49	31,339	24	22,304	5	26,112	6	33,507	8	28,608	8

*Regular treatments (plots 1, 2, 3) applied Aug. 20 and 30, Sept. 10 and 18, and Oct. 4. Concentration doubled in Oct. 4 application.
†Soil treatment consisting of 1 ounce Systox in 10 gallons water used at rate of 1 pint per plant July 3. Used 36 ounces Systox per acre.
‡Because of a very heavy infestation on both Systox plots, TEPP and Metacide were substituted for the Systox in the Sept. 18 and Oct. 4 applications.
§Applied as a foliage application July 10.

infested with aphids during the entire season. These untreated areas served as a reservoir from which aphids were continually migrating to re-infest the treated plots. In other words, the problem of keeping a planting free of aphids would have been much easier if the whole planting had been treated with either TEPP or parathion. For example, it is questionable whether it would have been necessary to increase the dosage of TEPP and parathion from 1 to 2 pints had the whole field been treated.

Pea Aphid and Pea Weevil

The low gallonage spraying method was tested on peas for the control of the pea weevil, *Bruchus pisorum (L.)*, and the pea aphid, *Macrosiphum pisi* (Kltb.), during the 1950 and 1951 seasons. This work was done by Dr. A. C. Davis of this Station and the data are being published elsewhere. The results of these tests show that 1 pint of a 25 per cent parathion emulsion or 1 quart of a 25 per cent DDT emulsion will give satisfactory control of the aphid and weevil. The test materials were applied with a brush-type boom arrangement, using a pressure of 80 P.S.I. and applying 20 to 25 gallons of solution per acre.

Details of the Sprayer

The low gallonage, row crop sprayer used for insecticide applications is basically a weed sprayer with boom and drop pipes adapted to the plants being sprayed. This sprayer consists essentially of (1) pump, (2) spray tank, (3) pressure regulator and gauge, (4) connecting hose and shut-off valve, (5) strainers, (6) sprayer frame, and (7) boom, drop pipes, and nozzles.

The sprayer that was used in the various tests described in this bulletin was homemade, but the following description refers to both homemade and commercially manufactured sprayers. The detailed plans of the sprayer are shown in Fig. 3.

The Pump

The pump is an important part of the sprayer and considerable care should be given to its selection. The life of the pump is largely determined by its materials of construction and its ability to withstand the abrasive and corrosive action of spray liquids.

Pumps can be roughly classified as positive displacement and non-positive displacement. The positive displacement pumps are self-priming and require a by-pass valve for protection when the discharge is shut off while the pump is running. Examples of this type of pump

are the rotary gear, vane type, piston, and diaphragm. The nonpositive displacement pumps are usually not self-priming except when fitted with special priming devices or when located below the liquid to be

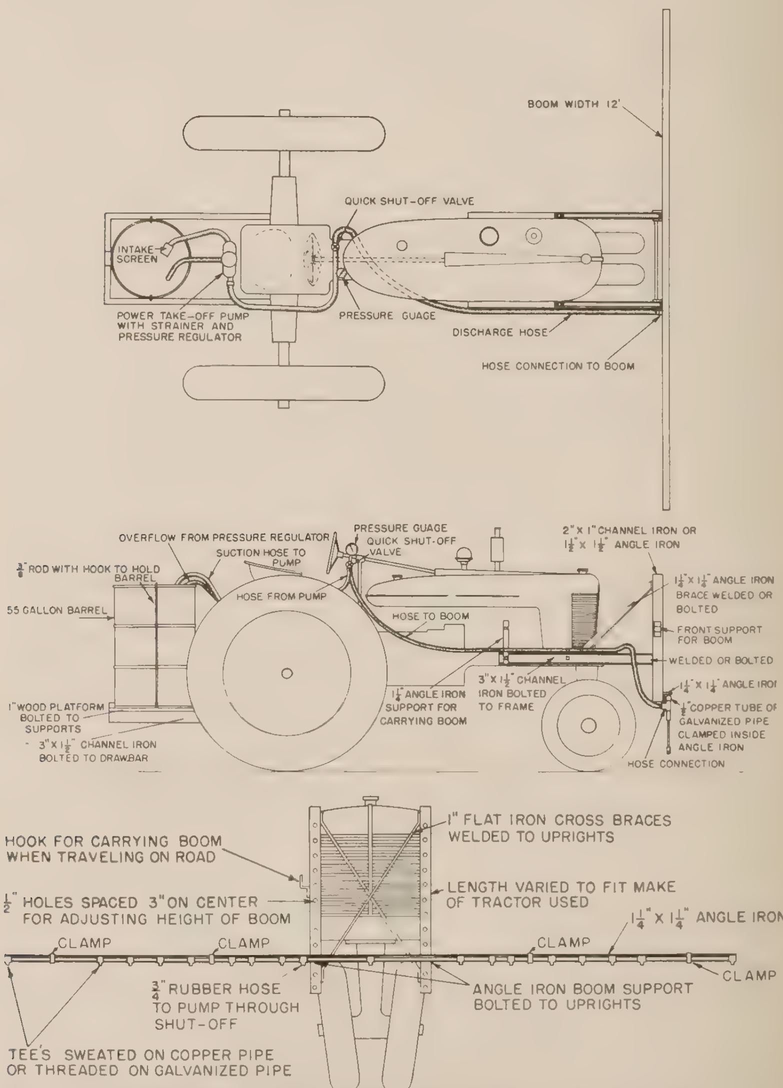

FIG. 3.—Detailed plan of sprayer. *Top,* top view; *center,* side view; *bottom,* front view.

pumped. They do not usually require pressure relief valves. Examples of this type of pump are the centrifugal and the flexible impeller.

The *rotary gear pump* is commonly used for applying low volume sprays. It can either be an internal or an external gear type depending on the relative position of the two gears. The action of the pump depends upon close fitting gears and small housing clearances. The use of abrasive or gritty materials will cause excessive wear and affect the operation and shorten the useful life of the pump. The discharge rate of the gear pump depends directly upon the speed at which the pump is operated. Pressures of over 100 P.S.I. can be developed.

The *vane type pump* is capable of maintaining pressures up to 100 P.S.I. or more. The action of the pump depends upon centrifugal force acting on movable vanes or rollers, and therefore, small amounts of gritty or abrasive materials can be used without severe damage.

The *diaphragm pump* consists of a single or multiple flexible diaphragm. The pumping action depends upon the reciprocation or pulsation of the diaphragm. As the valves are the only moving parts in contact with the liquid the pump can handle gritty materials very satisfactorily. Pressures of 100 P.S.I. can be developed, but a pressure chamber is required to prevent pressure fluctuations.

The *piston pump* is generally used where high pressures are required and where the solution being used contains materials in suspension. It is usually heavier and more expensive than other pumps and generally is not suited for a low volume sprayer. However, if the sprayer is to be used for other types of spraying requiring higher pressures, it should be considered.

The *flexible impeller pump* consists of a rubber impeller, and it is self priming. Most pumps of this type are not able to develop pressures above 50 P.S.I. and are, therefore, unsuitable for applying insecticide sprays in a low volume sprayer. A few, however, are capable of developing pressures up to 100 P.S.I. Solutions containing abrasive materials can be used without severe damage, but oils and some chemicals will cause deterioration of the rotors. This pump is lubricated by the spray liquid and it will wear out rapidly if run dry.

The *centrifugal pump* is a high speed, high volume pump and may require operating speeds of 1,200 to 3,500 R.P.M. to develop the necessary pressure. It is not commonly used for low volume spraying.

These are but a few of the many different types of pumps available. Some will perform satisfactorily for low volume spraying while others are unsatisfactory.

The size or capacity[10] of the pump has to be adequate to provide for the desired spray discharge, the by-pass liquid for agitation, and allowances for leakage and wear. In actual practice a pump for this type of sprayer should have a capacity of at least 5 G.P.M. Ten G.P.M. would be preferred.

Some pumps are designed to be mounted directly on the power take-off shaft of the tractor.[11] This shaft supports the pump but a chain or stabilizer bar is necessary to prevent the whole pump from rotating. Pumps mounted in this way should be able to deliver the rated discharge pressure at the usual power take-off speed of 540 R.P.M. Pumps requiring higher speeds must be driven through speed-up pulleys from the power take-off shaft or belt pulley. Figure 1 shows a pump mounted on the power take-off of the experimental sprayer.

Pressure Gauges and Regulators

The discharge per nozzle varies as the liquid pressure. It is therefore essential that the pressure be known and accurately controlled. This pressure can be determined by a pressure gauge and controlled by a pressure regulator. A pressure gauge suitable for a low gallonage sprayer should have at least a 3-inch diameter face with a maximum reading of 150 P.S.I. The gauge can be mounted on the boom or on the supply line to the boom, provided it can be easily seen by the operator. The gauge should be checked for accuracy at least once a year by comparing it with another gauge known to be accurate or by having it calibrated by a reliable service man.

---

[10] The actual pump capacity in G.P.M. required for spraying plus a 20 per cent allowance for wear can be figured as follows:

$$\text{G.P.M.} = \frac{\text{M.P.H.} \times \text{Ft. per Mile} \times \text{Boom Length in Ft.} \times \text{G.P.A.}}{\text{Minutes per Hour} \times \text{Sq. Ft. per Acre} \times \text{Factor for Wear}}.$$

The constants (Ft. per Mile, Minutes per Hour, Sq. Ft. per Acre, and Factor for Wear) can be combined into one constant. This constant, 396, can then be combined with the remaining variables to form a shorter formula as follows:

$$\text{G.P.M.} = \frac{\text{M.P.H.} \times \text{G.P.A.} \times \text{Boom Length in Feet}}{396}.$$

[11] The approximate power needed for the pump can be determined by the water horsepower formula:

$$\text{H.P.} = \frac{\text{Pounds Pressure} \times \text{G.P.M.}}{1{,}730 \times \text{Efficiency}}.$$

The efficiencies vary between 20 and 80 per cent, but the exact figure can be obtained from the pump manufacturer. The H. P. required is of little importance if the pump is to be powered by the tractor. If, for any reason, a separate engine is used to operate the pump, this formula can be used to determine the H.P. requirements of the auxiliary engine.

A pressure regulator is either built into the pump or it is a separate unit located in the discharge line between the pump and the spray boom. The pressure regulator usually consists of a spring-loaded by-pass valve with a screw or handle to change the spring tension and indirectly the liquid pressure. In operation the pressure regulator allows the excess liquid not discharged through the boom to be returned directly to the tank through a return hose or to be recirculated through the pump. When the discharge line to the boom is shut off, all of the liquid is returned to the tank through the by-pass valve. This action prevents excess pressure from being built up in the line.

Spray Tank and Agitation

A metal or a wooden tank may be used for this sprayer, but a metal tank is better in many respects. It is easier to clean, less likely to leak, and more convenient to mount. The metal tank may be galvanized on the inside, coated with a chemical resistant plastic, or left bare. The plastic coating is sometimes affected by the solvents in the insecticide and when this happens the loosened coating peels off and plugs the strainers and nozzles. An uncoated tank will rust rapidly unless given special care. Coating the inside of the tank with oil before storage will help prevent excessive rusting. All sprayer tanks should be flushed with clean water after every operation and before storage.

The size of the tank depends upon the operator's preference and the size of the tractor on which it is to be mounted. For homemade and some commercial sprayers, a clean 55-gallon barrel makes a satisfactory tank. Care must be taken, however, to provide a spill proof cover as the insecticide should not be allowed to splash on the operator. Some of the new insecticides are just as hazardous through skin absorption as when inhaled or taken orally.

The tank can be mounted on either the sides or on the rear of the tractor, although the rear mount is usually preferred because of the ease of mounting. If the side mount is used, care should be taken to prevent the tank from obstructing the operator's view. A side-mounted tank was used in the sprayer shown in Fig. 1.

Some agitation or mixing of the materials in the tank is necessary for most mixtures of insecticides and water, although the amount of agitation will vary with the material being used. This is, however, not a serious problem in the case of the low volume insecticide sprayer because the insecticides are used in the emulsion form. They are readily miscible with water and will remain dispersed throughout the spray solution with little agitation. The agitation produced in the spray tank by the

liquid being returned through the by-pass line, while not very efficient, is satisfactory in most cases if enough liquid is circulated. The solution is usually returned through a 1-inch pipe which opens near the bottom of the tank. Somewhat better agitation will be obtained if this pipe is closed at the bottom and the solution is forced through a series of small holes drilled along its length. Care should be taken not to restrict the flow of the solution through the by-pass line as this will result in a higher discharge pressure.

Mechanical agitation is efficient and provides a vigorous mixing action. Usually this special mixing action will not be required. In mechanical agitation a series of blades or paddles are mounted on a shaft which runs through the sprayer tank. Power for rotating the agitator shaft is usually provided from the power take-off shaft.

Shut-Off Valve, Connecting Hose, and Strainers

A shut-off valve placed between the pump and the boom is very essential in the operation of the low volume sprayer. This valve has to be within easy reach of the operator. A quick acting shut-off valve or a spring-loaded valve may be used for this purpose. The openings in these valves should be the same size as the openings in the line and the boom. The connecting hose should be chemical resistant and capable of carrying pressures of 150 P.S.I. A ¾-inch high-pressure hose was used on the homemade sprayer.

A system of strainers is necessary to prevent clogging of the lines and nozzles and to reduce wear on the pump, pressure regulator, and nozzles. This system should consist ideally of four separate strainers, as follows: (1) A tank strainer, located at the filler opening, to prevent trash or other foreign material from entering the tank. A 50-mesh strainer screen or ordinary window screen works satisfactorily for this purpose. (2) A pump suction-line strainer, between the tank and the inlet side of the pump, is used to strain the liquid entering the pump. This line strainer should consist of 50-mesh screen, the area of which should be at least 10 times the area of the suction line to prevent "starving the pump". The strainer should be easily accessible and should be cleaned once a day or more often if necessary. (3) A pump discharge-line strainer, in the discharge line between the pressure regulator and the boom, is used to strain all material entering the boom. This strainer should be made of 100-mesh screen and should be cleaned once a day. (4) The nozzle strainer is part of the nozzle assembly and is used to further strain the materials and prevent nozzle clogging. The screen should be 100-mesh. This screen and the nozzles should be cleaned frequently.

Sprayer Frame

The sprayer frame should be light in weight but rigid and may be made of wood or iron. It should also be constructed in such a way as to be easily removable. For a front-mounted boom it is necessary to have a frame to support the boom and another to support the tank which will probably be mounted on the back of the tractor. The frame shown on the sprayer in Fig. 3 (top) is intended to serve as a guide rather than a detailed plan to be followed. Modifications of this plan will have to be made for the various types and models of farm tractors.

Boom Construction and Mounting

A 12-foot boom has been found to be convenient and a satisfactory length for an insecticide row crop sprayer. It can be made of galvanized iron pipe, rust-resistant alloy pipe, or copper tubing. The pipe size is important because it has to be large enough to prevent a pressure drop in the nozzles at the end of the boom. A 12-foot boom requires a $\frac{3}{4}$-inch iron pipe or if copper tubing is used the $\frac{1}{2}$-inch size is sufficient. Copper tubing is superior to iron pipe because it is less likely to corrode and scale and thus cause nozzle plugging. If copper tubing is used for the boom, it should be supported with angle iron.

The boom can be made in one piece or, if desired, made in sections and hinged to permit travel on roads or through gates. The hinged boom should be made in three separate sections and these can be connected with a hose between sections or three separate hoses connecting the sections to the discharge line. Most commercial insecticide sprayers have a three section hinged boom with each section connected to the main discharge hose. The one-piece boom is easier to construct but provisions must be made for removing the boom and transporting it when travelling on roads. The drawings shown in Fig. 3 (top and bottom) have two brackets alongside the tractor for transporting the one-piece boom.

The spray boom may be mounted on the front of the tractor, between the front and rear wheels or on the rear. There are certain advantages and disadvantages for each type of mounting. The advantages for the front mount are:

1. Sprayer is easier and more convenient to control if mounted in front of the operator.

2. It is easier to center the spray pattern on the rows and to see clogged nozzles.

3. Less likely to damage boom by hitting obstructions.

A center-mounted boom has the same advantages as the front-

mounted, but it is more expensive to mount and there is little space for adjustment.

The advantages of the rear-mounted boom are:

1. It is easier and cheaper to mount.

2. There is less likelihood of the operator coming in contact with the insecticide spray.

3. For crops such as broccoli and cauliflower where the leaves may be brushed by the tractor axles the rear mounting is probably better. This is because some of the spray may be dislodged by the tractor axles before it is dry when applied with a front-mounted boom.

4. The sprayer is in full operation when starting at the end of the field. Tractors not equipped with a live power take-off cannot give an immediate spray discharge when starting. Therefore a rear-mounted boom does not leave an unsprayed strip at the end of the field as does a sprayer with a front-mounted boom.

A means has to be provided for adjusting the boom height. The sprayer shown in Fig. 3 (bottom) has a series of holes drilled in the stationary front mounting supports and the boom is raised and lowered by removing two bolts and replacing them in the desired holes. Height adjustment can also be accomplished by having the boom mounted on a hinged support.

The kind of outlet for nozzles or drop pipes depends on the type of boom. For an iron pipe boom the outlet may be a tee fitting or a welded outlet, while for a copper tube a soldered tee fitting is used. On the experimental sprayer the drop pipes were attached to the boom by means of tee fittings. These fittings were $\frac{1}{2} \times \frac{1}{2} \times \frac{1}{4}$ inch and were put in the boom by means of a threaded adapter which was sweated on the copper tube. The spacing of the outlets and the arrangement of drop pipes and nozzles on the boom depend on the row width and the type of crop being treated.

It would be economical and convenient to use the same basic boom for spraying all the various row crops and row width combinations. However, such a boom would obviously be impractical. It is therefore necessary to have either an individual boom for spraying each crop or possibly a boom in which the outlets are arranged so that two or three crops with different row widths can be sprayed. Figure 4 shows several suggested booms for use on crops of various types and row widths.

The drop pipes are used to position the nozzles so that the spray can be directed toward the side of the plant or to the undersurface of the leaves. Figure 5, right, shows one type of drop pipe which consists of a copper tube fitted with a short piece of rubber hose to make it flexible

FIG. 4.—Four suggested boom combinations with the outlets spaced for spraying various crops and row widths.

and prevent breakage when striking obstructions. Figure 5, left, shows another type of drop pipe. This consists of a light band of sheet metal which clamps on the boom. The double swivel at the bottom of the drop pipe is connected to the boom with a short piece of hose. This type of drop pipe is more rigid than the copper tube and offers a convenient method of adjusting the drop pipes to conform to different row widths.

Nozzle Arrangements

The nozzle arrangement is an important consideration and will vary with the crop being treated. Drop pipes should be used for all row crops. For peas and other crops grown in a similar manner the drop pipe is unnecessary and a simple brush-type arrangement of nozzles is satisfactory.

In treating beans (Fig. 6) the drop pipe is used with a ground clearance of about 4 inches. The nozzles are directed upward to ensure thorough coverage of the undersurface of the leaves. This is important in the control of the Mexican bean beetle since the insect feeds on the undersides of the leaves.

The same basic arrangement is used for treating carrots (Fig. 7) as that used for beans. The modification is that the boom is raised so

that the nozzles in the drop pipe are about level with the tops of the plants. The nozzles are directed inward and slightly downward.

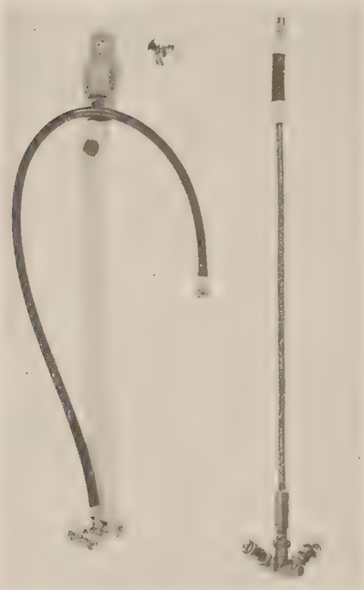

Fig. 5.—*Right,* drop pipe with piece of hose, double swivel connector, and nozzles. *Left,* another type of drop pipe consisting of a band of sheet metal with a double swivel connector and a short piece of hose to connect the nozzles to the outlet in the boom.

For treating cabbage (Fig. 8) the drop pipe is used with a ground clearance of about 10 inches and the nozzles are directed inward toward the side of the plant. A third nozzle is mounted directly above the row and the spray is directed downward toward the top of the plant.

For treating broccoli (Fig. 9) the drop pipe is used with a clearance of about 10 to 12 inches from the ground. The nozzles are tipped upward to direct the spray toward the undersurface of the leaves. When the plants are small, one nozzle is used above the row as in the case of cabbage. When the plants are about one-half grown two nozzles are used above the row. The spray from one of these nozzles is directed slightly backward and from the other slightly forward.

In treating peas (Fig. 10) the nozzles are mounted in the boom at

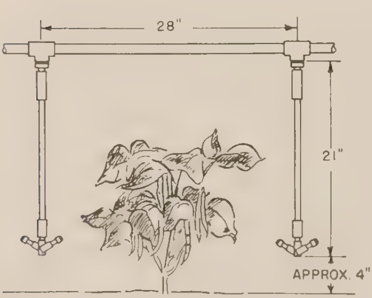

Fig. 6.—Nozzle and drop pipe arrangement for spraying beans, with row spacing 28 inches.

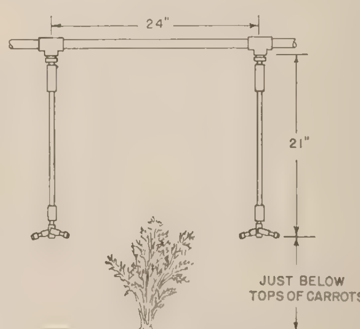

Fig. 7.—Drop pipe and nozzle arrangement for spraying carrots, with row spacing 24 inches.

intervals of 18 inches. The boom is operated at a height of about 18 inches above the tops of the peas.

Various other drop pipe and nozzle arrangements may be used for treating row crops. The important point is that the spray should be directed so that the plant is as completely and uniformly covered as possible.

Nozzle Types, Care, and Selection

The nozzles used for low volume insecticide spraying are the same as those used for low volume weed spraying and are available from several manufacturers. These nozzles can be purchased with ¼-inch male or female pipe threads, but the male threads are more adaptable for mounting. The tip or orifice disk is removable and interchangeable in some nozzles, while in other types the opening is cut in the nozzle body and the entire nozzle has to be replaced to change the orifice size. A few nozzles are available with hardened steel tips. These nozzles resist wear remarkably well and do not have to be replaced as often as those with brass tips. Nozzles giving either a cone-shaped spray pattern or a flat, fan-type pattern are available. The fan-type have given somewhat better insect control with the low volume sprayer and are recommended at present. A typical nozzle is shown in Fig. 11.

Nozzles should be cleaned frequently to prevent the accumulation of sludge on the screen and the

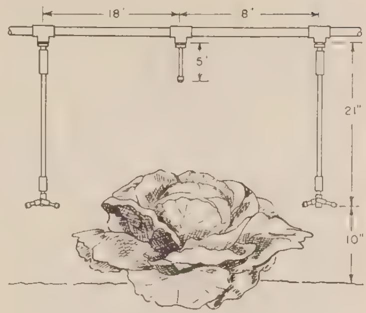

Fig. 8.—Drop pipe and nozzle arrangement for spraying cabbage, with row spacing 36 inches.

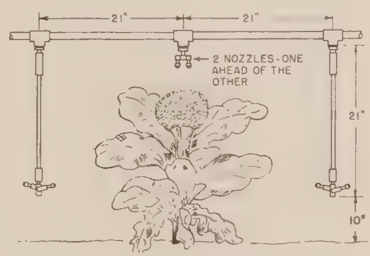

Fig. 9.—Drop pipe and nozzle arrangement for spraying broccoli, with row spacing 40 inches.

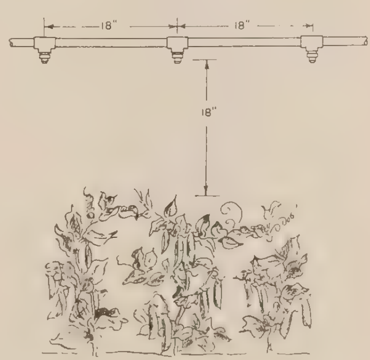

Fig. 10.—Nozzle arrangement for spraying peas.

Fig. 11.—A typical nozzle used for applying low volume sprays. From bottom to top: body, strainer, cap, and orifice tip.

eventual clogging of the nozzles. If the nozzle becomes plugged, it should be cleaned with a piece of wood or other soft object and never with a piece of wire or other metal object. The latter may enlarge the orifice opening which will increase the spray discharge and result in wasted material. A worn nozzle will have the same effect. The nozzles should, therefore, be checked rather frequently and should be replaced if they show excessive wear.

The successful operation of a low volume insecticide sprayer requires that the spray output be controlled and regulated very closely. This, in turn, depends on the correct selection of the nozzle orifice size. Unfortunately, there is no standardization of nozzle designation since each manufacturer has his own system of numbering. Some nozzles are numbered according to the orifice size, while others are numbered according to the discharge rate per unit of time at a given pressure. Nozzle manufacturers supply tables for all the different brands of nozzles. These data sheets give the discharge rate of the various nozzles at a given pressure and can be used to select the correct size nozzle for the crop to be sprayed. To select correctly the nozzle orifice size required, the operator should have the following information:

1. Type of nozzle. A flat, fan-type nozzle with an 80 degree fan angle has been found to be satisfactory for all insecticide row crop spraying.

2. The desired liquid pressure. 80 P.S.I. has been found to be satisfactory for all insecticide row crop spraying.

3. Amount of spray liquid to be applied per acre. It has been found that this should be about 15 to 20 G.P.A.

4. Row spacing and number of nozzles used per row.

5. Speed of travel in miles per hour or feet per minute.

If the above information is given to the dealer, he should be able to determine the correct nozzle size to use. If nozzle data sheets are not readily available, Tables 8 and 9 can be used to select the correct nozzle size when gallons per acre, speed, row spacing, and number of nozzles per row are known. These charts are for two of the more common brand nozzles and were made up from the respective manufacturers' data sheets.[12]

As an example, an insecticide application is to be made on beans with the rows spaced at 30 inches. Approximately 20 gallons is to be applied per acre at 4 M.P.H. and at a pressure of 80 P.S.I. Two nozzles are to be used per row. In Table 8 it will be seen that an 80015 nozzle tip will discharge 20.8 G.P.A. when used under the conditions listed above. It is then only necessary to add the recommended amount of insecticide to 21 gallons of water.

The information given above under nozzle selection should serve as a guide in selecting the appropriate nozzle orifice size for any particular spraying operation. However, it should be noted that in following these directions based on nozzle discharge rates, the number of gallons applied per acre will be only approximate. This is because there is a variation in the nozzle discharge rate between the manufacturers' specifications and the actual discharge rate obtained under operating conditions. This variation is chiefly due to changes in the flowability of the solution when an insecticide in the emulsion form is added to water.

---

[12]The discharge rate of the various nozzles at 80 P.S.I. pressure was converted to G.P.A. from the following formula:

$$\text{G.P.A.} = \frac{\text{G.P.M. per nozzle} \times \text{Sq. Ft. per Acre} \times \text{Minutes per Hour} \times \text{Inches per Foot} \times \text{No. Nozzles per Row}}{\text{Row Spacing in Inches} \times \text{M.P.H.} \times \text{Feet per Mile}}.$$

The constants (Sq. Ft. per Acre, Minutes per Hour, Inches per Ft., and Ft. per Mile) may be combined to form one constant. This constant, 5,940, can then be combined with the remaining variables to form a shorter formula, as follows:

$$\text{G.P.A.} = \frac{\text{G.P.M. per Nozzle} \times 5{,}940 \times \text{Number of Nozzles per Row}}{\text{Row Spacing in Inches} \times \text{M.P.H.}}.$$

Other manufacturers of nozzles suitable for low gallonage spraying are as follows: Accessories Manufacturing Co., Inc., 301 Admiral Boulevard, Kansas City 6, Mo.; Delavan Manufacturing Co., 3007 Sixth Avenue, Des Moines, Iowa; Hanson Chemical & Equipment Co, Beloit, Wisc.; O. W. Kromer Co., 1120 Emerson Avenue, North Minneapolis 11, Minn.; Automatic Equipment Mfg. Co., South Sioux City, Neb.; H. D. Hudson Manufacturing Co., 589 East Illinois Street, Chicago 11, Ill.

TABLE 8.—*Teejet nozzle selection chart for low volume insecticide spraying.**

Nozzle number	Liquid pressure, P.S.I.	Capacity in G.P.M.	Row spacing and nozzles per row	Gallons per acre				
				2 M.P.H.†	3 M.P.H.	4 M.P.H.	5 M.P.H.	7 M.P.H.
800067	80	0.09	1 nozzle per 18 inches	15.0	10.0	7.5	6.0	4.3
			2 nozzles per 28 inches	19.2	12.8	9.6	7.7	5.5
			2 nozzles per 30 inches	17.8	12.0	9.0	7.2	5.1
			2 nozzles per 32 inches	16.8	11.2	8.4	6.7	4.8
			3 nozzles per 36 inches	22.3	14.9	11.2	8.9	6.4
			4 nozzles per 42 inches	25.5	17.0	12.7	10.2	7.3
8001	80	0.14	1 nozzle per 18 inches	23.1	15.4	11.5	9.3	6.7
			2 nozzles per 28 inches	29.7	19.8	14.8	11.9	8.5
			2 nozzles per 30 inches	27.7	18.5	13.9	11.1	7.9
			2 nozzles per 32 inches	26.0	17.4	13.0	10.4	7.5
			3 nozzles per 36 inches	34.7	23.1	17.4	13.9	9.9
			4 nozzles per 42 inches	39.5	26.3	19.7	15.8	11.3
80015	80	0.21	1 nozzle per 18 inches	34.7	23.1	17.4	13.9	9.9
			2 nozzles per 28 inches	44.6	29.7	22.3	17.9	12.8
			2 nozzles per 30 inches	41.6	27.8	20.8	16.7	11.9
			2 nozzles per 32 inches	39.0	26.0	19.5	15.6	11.2
			3 nozzles per 36 inches	52.0	34.7	26.0	20.8	14.9
			4 nozzles per 42 inches	59.4	39.6	29.7	23.8	17.0
8002	80	0.28	1 nozzle per 18 inches	46.2	30.9	23.1	18.5	13.4
			2 nozzles per 28 inches	59.4	39.6	29.6	23.8	17.0
			2 nozzles per 30 inches	55.4	37.0	27.8	22.2	15.8
			2 nozzles per 32 inches	52.0	34.8	26.0	20.8	15.0
			3 nozzles per 36 inches	69.4	46.2	34.8	27.8	19.8
			4 nozzles per 42 inches	79.0	52.6	39.4	31.6	21.5

*Manufactured by Spraying Systems Co., 3201 Randolph St., Bellwood, Ill.
†The equivalent of 2, 3, 4, 5, and 7 miles per hour in feet per minute is 176 ,264, 352, 440, and 616, respectively.

TABLE 9.—*Monarch nozzle selection chart for low volume insecticide spraying.**

Nozzle number	Liquid pressure, P.S.I.	Capacity in G.P.M.	Row spacing and nozzles per row	Gallons per acre				
				2 M.P.H.†	3 M.P.H.	4 M.P.H.	5 M.P.H.	7 M.P.H.
22	80	0.097	1 nozzle per 18 inches	16.0	10.7	8.0	6.4	4.7
			2 nozzles per 28 inches	20.6	13.7	10.3	8.2	5.9
			2 nozzles per 30 inches	19.2	12.8	9.6	7.7	5.5
			2 nozzles per 32 inches	18.0	12.0	9.0	7.2	5.2
			3 nozzles per 36 inches	24.0	16.0	12.0	9.7	6.9
			4 nozzles per 42 inches	27.5	18.3	13.7	11.0	7.9
28	80	0.145	1 nozzle per 18 inches	24.0	16.0	12.0	9.6	6.9
			2 nozzles per 28 inches	30.8	20.5	15.4	12.3	8.8
			2 nozzles per 30 inches	28.7	19.2	14.4	11.5	8.2
			2 nozzles per 32 inches	26.9	18.0	13.5	10.8	7.7
			3 nozzles per 36 inches	35.9	23.9	17.9	14.3	10.3
			4 nozzles per 42 inches	41.0	27.3	20.5	16.4	11.7
32	80	0.175	1 nozzle per 18 inches	29.1	19.4	14.5	11.6	8.3
			2 nozzles per 28 inches	37.1	24.8	18.6	14.9	10.6
			2 nozzles per 30 inches	34.8	23.2	17.4	13.9	10.0
			2 nozzles per 32 inches	32.5	21.7	16.2	13.0	9.3
			3 nozzles per 36 inches	43.4	28.9	21.7	17.4	12.4
			4 nozzles per 42 inches	49.6	33.0	24.8	19.8	14.2
35	80	0.230	1 nozzle per 18 inches	38.0	25.3	19.0	15.2	10.9
			2 nozzles per 28 inches	49.0	32.6	24.5	19.6	14.0
			2 nozzles per 30 inches	45.6	30.4	22.8	18.2	13.0
			2 nozzles per 32 inches	42.7	28.5	21.3	17.1	12.2
			3 nozzles per 36 inches	57.0	38.0	28.5	22.8	16.3
			4 nozzles per 42 inches	65.0	43.5	32.6	26.1	18.6

*Manufactured by Monarch Manufacturing Works, Inc., 2501 East Ontario St., Philadelphia 34, Pa.
†The equivalent of 2, 3, 4, 5, and 7 miles per hour in feet per minute is 176, 264, 352, 440, and 616, respectively.

Calibration

In addition to the selection of the correct nozzle size for spraying any particular crop, some growers may wish to go further and calibrate the machine to determine the exact number of gallons being applied per acre. Calibration may also be necessary when nozzles begin to show wear. To insure correct application, the variables affecting gallons per acre should be determined and then the sprayer should be calibrated under actual operating conditions. The number of gallons applied per acre depends on the following:

1. Speed of sprayer.
2. Nozzle spacing.
3. Nozzle orifice opening.
4. Liquid pressure.

Most sprayer operations will be in the speed range between 2 and 7 M.P.H. Slower speeds are not practical because of the excessive time required to do the job, while faster speeds are only possible on very smooth fields. It is also harder to obtain a thorough coverage at speeds above 7 M.P.H. In actual practice, 4 M.P.H. is commonly used for most spraying operations.

As gallons per acre are affected by sprayer speed, this speed has to be known and accurately controlled to insure a thorough spraying job. A known and controlled speed can best be accomplished by using a commercially available low-recording tractor speedometer (Fig. 12). This type of speedometer can be purchased for a very reasonable amount and can be mounted on any tractor. The speed of the sprayer can also be determined by measuring a certain length of the field to be sprayed and timing the sprayer for this distance. A stop watch or the second hand of an ordinary watch can be used. The figures obtained can be converted to miles per hour by the following formula:

$$\text{M.P.H.} = \frac{\text{Distance Covered in Feet}}{\text{Seconds Required to Cover Distance} \times 1.47}.$$

For example, an operator measures off 300 feet and covers this distance in 51 seconds. $\text{M.P.H.} = \frac{300}{51 \times 1.47} = 4$. The other variables affecting the rate of application, nozzle spacing, nozzle size, and liquid pressure have been discussed.

There are many ways to calibrate a sprayer accurately. The actual discharge of the spray mixture from one nozzle can be collected in a pail or small container and measured for a given length of time, usually 1 minute. It is usually a good plan to measure the discharge from three

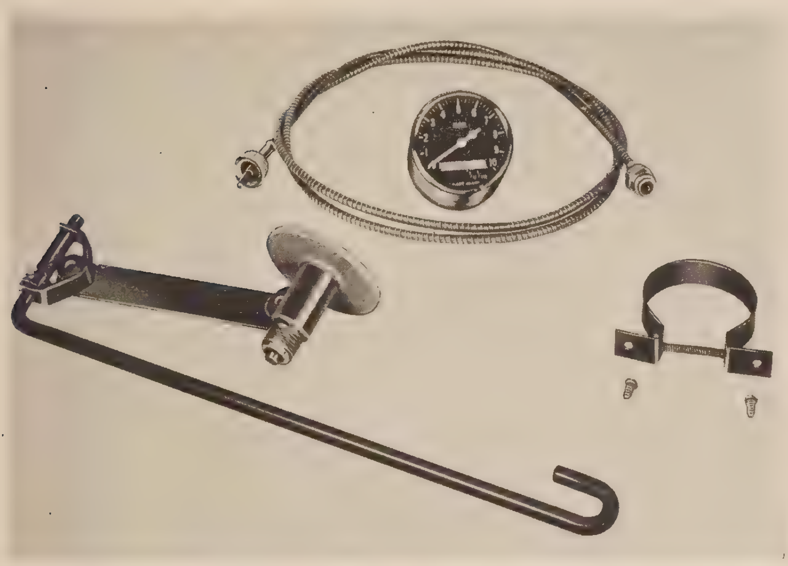

FIG. 12.—A low-recording tractor speedometer, showing traction wheel and mounting bracket, flexible cable, speedometer head, and mounting bracket. (Courtesy Stewart-Warner Corp., 1826 Diversy Parkway, Chicago 14, Ill.)

or four nozzles and average the amounts collected because there is often a variation in the discharge rate between individual nozzles. This figure can be converted to gallons per minute per nozzle. The G.P.M. can then be converted to G.P.A. by the following formula:

$$\text{G.P.A.} = \frac{5{,}940 \times \text{Number of Nozzles per Row} \times \text{G.P.M. per Nozzle}}{\text{Row Spacing in Inches} \times \text{M.P.H.}}.$$

For example, if 2 pints of spray mixture are collected from one nozzle in 1 minute, what will be the rate in G.P.A. when spraying beans planted in 30 inch rows, using two nozzles per row and travelling 4 M.P.H.? Two pints per minute equals $\frac{1}{4}$ or 0.25 gallon per minute.

$$\text{Therefore, G.P.A.} = \frac{5{,}940 \times 2 \times 0.25}{30 \times 4} = 24.75.$$

It is possible to purchase a special calibration jar that eliminates the mathematics of calculating discharges. This jar consists of a series of vertical scales corresponding to various nozzle spacings. To use, the jar is attached to the boom where it collects the discharge from one nozzle. The sprayer is operated for 1 minute or for a certain measured

distance and the G.P.A. can be read directly from the jar by comparing the liquid level with the appropriate nozzle spacing scale.

A simple and practical means of calibrating the sprayer in the field may be used during the first round of operation. This method consists of determining the number of acres covered during one round and measuring accurately the amount of spray applied. The amount of liquid applied can be measured with a measuring stick calibrated in gallon intervals. It can also be determined by measuring the amount of liquid required to refill the tank. The G.P.A. can then be determined by dividing the number of gallons used by the number of acres covered.

Conclusions and Recommendations

Sufficient information has been accumulated, both experimentally and by growers, to show that the low volume method of insecticide application using a weed control type sprayer is a practical means of insect control for certain vegetable crops.

This method of application is probably not any more effective than the present methods of dusting and high gallonage spraying. It does, however, have some rather definite advantages. It is cheaper. This is true both from the standpoint of the cost of the sprayer and in the cost of the insecticide formulation used as compared with an insecticide dust.

The grower is not restricted as much in his spraying operations by windy weather as he is when using dusts. This means that the treatment can be applied at the recommended time when it will result in maximum effectiveness.

There is less insecticide loss when it is applied in a low volume sprayer because practically all of the material is actually deposited on the plant.

It is not possible to use insecticides or fungicides in the form of wettable powders in this type of sprayer because there is insufficient agitation in the spray tank to keep wettable powders in suspension. Also, they cause excessive wear to some pumps and, sooner or later, cause nozzle clogging. This is the chief limitation of the low gallonage sprayer. This is not a serious objection so far as insecticides are concerned because most of them are now available in emulsion form. Fungicides, however, are commonly used in the form of wettable powders. This means that this machine is best adapted for treating crops which require insect control primarily. It will have less use on crops where a combination of insect and disease control is required.

This type of sprayer seems best adapted for applying between 15 and

20 gallons of solution per acre. It does not appear necessary to apply more than 20 gallons per acre to obtain coverage of the insecticide on most crops and it probably is not practical to use much less than 15 gallons. To apply less than 15 gallons per acre requires either the use of nozzles with a rather small orifice size which may cause nozzle clogging, or it will be necessary to operate the tractor at faster speeds than are feasible except in very level fields.

The pressure has been standardized at 80 P.S.I. This is because sprays applied for Mexican bean beetle control at this pressure were more effective than when applied at 40 P.S.I. It is realized, however, that the selection of this pressure is only tentative because further investigations may show that 80 P.S.I. is higher than necessary to obtain adequate insect control on some crops and not high enough for other crops.

The suggestions which follow for the use of the low gallonage sprayer on various vegetable crops are for conditions which prevail in western New York. The dosage of insecticide recommended is the amount required to treat 1 acre of the crop. This is the amount to use regardless of whether the sprayer is adjusted to apply 15, 20, or 25 gallons of solution per acre. These recommendations are based on formulations which contain 25 per cent parathion, 25 per cent DDT, or 20 per cent TEPP. These are equivalent to 2 pounds, 2 pounds, and 1.6 pounds, respectively, of the actual toxicant per gallon. If formulations are used which contain concentrations different than those listed above, it will be necessary to adjust the quantity of such formulations to give the required amount of actual toxicant per acre.

Mexican Bean Beetle and Leafhopper Control on Beans

One pint of 25 per cent parathion emulsion has proved very effective against the bean beetle. Metacide and Dilan have been tested less extensively, but they appear promising when used at the same rate as parathion. For a light infestation a single application is sufficient, but for a moderate to heavy infestation two applications at an interval of 7 to 10 days are necessary. Parathion is effective against both adult bean beetles and larvae.

Cabbage Caterpillars and Aphids on Cabbage

One quart of 25 per cent DDT emulsion is very effective against the cabbage caterpillars. For cabbage aphid control, 1 to 2 pints of 25 per cent parathion emulsion or 1 to 2 pints of 20 per cent TEPP may be used. Since caterpillars and aphids are usually on the plant at the same time, the DDT and parathion or TEPP may be combined to make

a single treatment. Two to four applications are necessary for adequate control, depending on the severity of the infestation.

Cabbage Caterpillars and Cabbage Aphids on Broccoli

The results obtained on broccoli insects in a single experiment in 1951 are promising, but the materials and methods given are only tentative. They are included here to serve only as a guide for anyone who may wish to try low volume equipment on broccoli.

Up to the time the center head begins to form (about two weeks before the beginning of harvest), 1 quart of 25 per cent DDT emulsion plus 1 pint of 25 per cent parathion emulsion or 1 pint of 20 per cent TEPP may be used. *After the center head begins to form,* use 1 to 2 pints of 20 per cent TEPP. This is effective against the aphid but will only kill the newly hatched caterpillars. Parathion emulsion used at the rate of 1 to 2 pints is effective against aphids and is more effective than TEPP against caterpillars. Parathion, however, leaves a more persistant residue than TEPP and it may be objectionable from this standpoint. Applications will usually be necessary at about 14-day intervals during July, August, and September. In the event that there is an outbreak of the cabbage aphid, it may be necessary to shorten this interval to 7 days for as long as the insect is prevalent.

Pea Aphids and Pea Weevil

One pint of 25 per cent parathion emulsion or 1 quart of 25 per cent DDT emulsion may be used. The DDT leaves a residue and it should not be used on vines which are to be fed as ensilage to livestock. Metacide has been tested less extensively than parathion and DDT, but it also appears effective against both species.

Precautions

The phosphate compounds, i.e., parathion, Metacide, and TEPP, are extremely poisonous and are hazardous to use if *handled carelessly.* This is true especially when they are used in concentrated form as in low volume spraying. The operator should be sure to wear an approved respirator, rubber gloves, and coveralls when handling and spraying phosphate materials.

When purchasing a DDT emulsion for use on cabbage or a related crop the prospective buyer should first ascertain from the dealer if the brand of emulsion is safe for the particular crop on which it will be used. The reason for this precaution is that there are a number of different kinds of solvents used in the preparation of DDT emulsions.

Some of these are perfectly safe for use on cabbage, while others are extremely injurious.

One question frequently asked about this type of sprayer is whether it is safe to use the same machine for applying both weed control chemicals and insecticides. *Owing to the difficulty of thoroughly removing 2,4-D and its related compounds from sprayers, it is felt that a sprayer for applying insecticides should be used only for that purpose.* It is possible that the pump and nozzles if washed thoroughly in an ammonia solution after being used to apply 2,4-D could be safely used for applying insecticides, but it would seem unwise to attempt to use the same hose, spray tank, and boom for both jobs.

Summary

The application of insecticides with a low volume sprayer for the control of insect pests of certain vegetable crops is described. The details of the construction of the sprayer are also given.

The sprayer is tractor-mounted and consists essentially of the pump operated by the tractor power take-off or by a belt and pulleys from the power take-off or pulley shaft, the connecting hose, spray tank, boom, drop pipes, and nozzles. Several different kinds of pumps are available for this type of sprayer. A rotary gear pump has been used exclusively for experimental work and has proved satisfactory. A clean 55-gallon drum mounted on a frame on the rear of the tractor provides a satisfactory spray tank. The boom can be constructed of either galvanized iron pipe or copper tubing. The latter is less likely to cause trouble through corrosion and nozzle clogging. In order to obtain uniform insecticide coverage of the plant, some type of drop pipe is necessary for spraying most crops. A piece of ¼-inch copper tube, in which a short piece of stiff rubber hose is inserted to prevent breakage, provides a satisfactory drop pipe. The use of a double swivel connector on the drop pipe aids greatly in adjusting the angle of the nozzles. This enables a more complete coverage of the plants.

Nozzles which produce a flat, fan-type spray pattern have given somewhat better insect control than the cone type and are therefore recommended. These nozzles are available in a wide range of orifice sizes and in several different fan widths. The 80-degree fan width has been used extensively in the experimental spraying and has proved satisfactory. Selection of the correct nozzle orifice size for any spraying operation can be determined from either the manufacturers' nozzle specifications or by referring to Tables 8 or 9.

The sprayer should be adjusted to apply the required amount of

insecticide in about 20 gallons of water per acre at 80 pounds per square inch. Both the gallonage and the pressure given are more or less tentative and may be changed as a result of further investigations. The speed at which the sprayer is operated depends on the nature of the field being sprayed. Four miles per hour is satisfactory for most fields.

The Mexican bean beetle, cabbage insects, and pea insects have been controlled satisfactorily with insecticide sprays applied with a low volume sprayer. At present it would seem that a sprayer of this type would find its greatest use in control of these insects.